B. AMENDMENT TO THE CLAIMS

This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

1. (currently amended) An apparatus for performing spectral analysis of a sample, the apparatus comprising:

a. a data acquisition system configured to measure a signal emitted from the sample in response to excitation energy applied thereto, and to average the measured signal over a plurality of measurements to generate an averaged signal for the sample;

b. a data processing system including:

a noise-reduction pre-processor configured to generate a noise-reduced signal from the averaged signal by creating ~~create~~ a vector space from said averaged signal, and generating ~~to generate~~ one or more singular values and corresponding eigenvectors of a correlation matrix constructed within said vector space, said vector space containing a noisefree signal subspace and a noise subspace, said singular values including noisefree singular values associated with said noisefree signal subspace, and noise singular values associated with said noise subspace; and

a spectral estimator configured to generate a spectrum for the sample by converting said noise-reduced signal into a frequency domain; and

c. a control system configured to identify, in a graph of the singular values of the correlation matrix constructed within the vector space created from the averaged signal, a gap between a smallest noisefree singular value and a first noise singular value, so as to request the data acquisition system to perform additional measurements of the signal emitted from the sample if no such separation gap can be identified, and to prevent further measurements of the signal emitted by the sample from being made by the data acquisition system if the gap has appeared and is stable.

2. (original) An apparatus in accordance with claim 1, wherein said spectral analysis comprises an NMR spectral analysis, said excitation energy comprises RF excitation pulses, and said measured signal comprises an NMR transient.

3. (previously presented) An apparatus in accordance with claim 1, wherein said control system comprises:

a. a graphics system adapted to generate the plot of said singular values;

b. a pattern recognition system adapted to identify the gap in said plot between said smallest noisefree singular value and said adjacent noise singular value, and to verify the stability of said gap; and

c. a command signal generator, responsive to said pattern recognition system, configured to generate an output signal requesting for more measurements from said data acquisition system, in the absence of an identifiable gap, and to generate an output signal requesting that further measurements be discontinued, if the appearance and the stability of said gap has been established by said pattern recognition system.

4. (previously presented) An apparatus in accordance with claim 1, wherein said noise-reduction preprocessor comprises:

a. a matrix generator configured to form the vector space from the averaged signal and constructing the correlation matrix within the vector space, the vector space containing the noisefree signal subspace and the noise subspace;

b. a matrix diagonalizer configured to diagonalize the correlation matrix to obtain its singular values and the corresponding eigenvectors, the singular values including noisefree singular values associated with the noisefree signal subspace, and noise singular values associated with the noise subspace; and

c. a signal projector configured to project the averaged signal onto the noisefree subspace to generate a noise-reduced signal.

5. (canceled)

6. (original) An apparatus in accordance with claim 1, wherein said data acquisition system is configured to sample each measured signal with a sampling period τ, and to average the corresponding sample points over said plurality of measurements, so as to store said averaged signal as a discretized set of N data points c_n ($n = 0, \ldots, N-1$).

7. (original) An apparatus in accordance with claim 6,

wherein said data processing system is configured to store each data point c_n as a noisefree component x_n ($n = 0, \ldots, N-1$) and a noise component ε_n ($n = 0, \ldots, N-1$), and to store each noisefree component x_n as a finite sum of damped complex harmonics weighted by respective coefficients.

8. (original) An apparatus in accordance with claim 7,

wherein said sum is over a number K of said damped complex harmonics, so that each noisefree component x_n can be stored as:

$$x_n = \sum d_k \exp(-iw_k\tau\, n)$$

where d_k represents the weighting coefficient of the k-th damped complex harmonics, and w_k represents the complex frequency of the k-th damped complex harmonics.

9. (original) An apparatus in accordance with claim 1, wherein said data acquisition system further comprises a windowing subsystem configured to apply a windowing filter to a Fourier transform of said averaged signal, so as to generate one or more decimated signals having a limited bandwidth.

10. (original) An apparatus in accordance with claim 9,

wherein said data processing system is configured to store the inverse Fourier transform of each decimated signal as a set of N_d decimated data points c_n^d ($n = 0, \ldots, N_d-1$),

and wherein said set of decimated data points have a signal length N_d that is substantially less than N and a sampling period τ_d that is substantially greater than τ.

11. (original) An apparatus in accordance with claim 10,

wherein said vector space created by said noise-reduction pre-processor comprises an M-dimensional vector space defined by a number $N_d - M + 1$ of linearly independent M-dimensional vectors, and

wherein said data processing system is configured to store said M-dimensional vectors in a form given by:

$$c_n^d = (c_n^d, c_{n+1}^d, \ldots, c_{n+M-1}^d),$$

where c_n^d represent said decimated data points.

12. (original) A system in accordance with claim 11, wherein said correlation matrix constructed by said matrix generator is Hermitian and covariant, and has a dimension MxM, and wherein said correlation matrix is formed from said M-dimensional vectors and in accordance with a formula given by:

$$R_{ij} = 1 / (N_d - M + 1) \sum c_{n+i-1} c^*_{n+j-1}$$

13. (original) A system in accordance with claim 11, wherein said projection of said averaged signal by said signal projector is based on a projection formula given by:

$$\vec{c}_n^{\,nr} = \sum_{k=1}^{K} (\vec{u}_k^*, \vec{c}_n)\vec{u}_k$$

where u_k represent said eigenvectors corresponding to said singular values.

14. (previously presented) A control system for controlling the acquisition and processing of data from a sample by an NMR apparatus so as to reduce the NMR data acquisition time required to generate a noise-reduced NMR spectrum for the sample, said NMR apparatus comprising a data acquisition system for measuring NMR response signals from the sample and averaging said response signals over a plurality of measurements, and a data processing system for processing said NMR response signals by extracting the singular values and the corresponding eigenvectors of a harmonic inversion correlation matrix formed in a vector space defined by data points sampled from said averaged signals, said vector space

containing a noisefree signal subspace and a noise subspace, said control system comprising:

a. a first processing system for identifying, in a graph of the singular values of the harmonic inversion correlation matrix, a gap between a noisefree singular value, associated with said noisefree signal subspace, and an adjacent noise singular value, associated with said noise subspace, so that said control system can request further measurements of NMR data from the sample by said data acquisition system if said gap cannot be identified; and

b. a second processing system for determining the stability of said gap, so that said control system can request further measurements of NMR data from the sample by said data acquisition system if said gap has not stabilized, and can discontinue any further measurements by said data acquisition system, if said gap has stabilized.

15. (previously presented) A control system for controlling the acquisition and processing of data from a sample by a spectral analysis apparatus so as to reduce the data acquisition time required to generate a noise-reduced spectrum for the sample, said apparatus comprising a data acquisition system for measuring response signals from the sample and averaging the response signals over a plurality of measurements, and a data processing system for processing said response signals by extracting the singular values and the corresponding eigenvectors of a harmonic inversion correlation matrix formed in a vector space defined by said averaged signals, said vector space containing a noisefree signal subspace and a noise subspace, said control system comprising:

a. a computer-usable medium having stored therein computer-usable instructions for a processor, wherein said instructions when executed by said processor cause said processor to:

1) identify, in a graph of the singular values of the harmonic inversion correlation matrix, a gap between a noisefree singular value,

associated with said noisefree signal subspace, and an adjacent noise singular value, associated with said noise subspace;

2) request further measurements of the response signals from the sample by said data acquisition system if said gap cannot be identified;

3) if said gap appears, determine the stability of said gap; and

4) request further measurements of the response signals from the sample by said data acquisition system, if said gap does not stabilize, and request that no further measurements be made by said data acquisition system, if said gap has stabilized.

16. (previously presented) A data processing system for processing NMR response signals measured from an NMR sample by an NMR data acquisition system, said NMR data acquisition system comprising an NMR transmitter for delivering RF excitation pulses to the NMR sample, an NMR receiver for detecting the response signals emitted by said NMR sample in response to said excitation pulses, and a measurement system for measuring said response signals and averaging said response signals over a plurality of measurements from said NMR sample, said data processing system comprising:

a. a noise-reduction pre-processor including: 1) a matrix generator for forming a vector space from said averaged signal and constructing a correlation matrix within said vector space, said vector space containing a noisefree signal subspace and a noise subspace; 2) a matrix diagonalizer for diagonalizing said correlation matrix to obtain its singular values and the corresponding eigenvectors, said singular values including noisefree singular values associated with said noisefree signal subspace, and noise singular values associated with said noise subspace; and 3) a signal projector for projecting said averaged signal onto said noisefree subspace to generate a noise-reduced signal; and

b. a spectral estimator for generating a spectrum by converting said noise-reduced signal into a frequency domain; and

c. a control system configured to identify a separation between a noisefree singular value and an adjacent noise singular value, in a graph of the singular

values, so as to allow the data acquisition system to perform additional measurements from said NMR sample if no such separation can be identified, and to discontinue further measurements by the data acquisition system if the appearance and stability of said separation can be established.

17. (previously presented) A computer-usable medium having stored therein computer-usable instructions for a processor, wherein said instructions when executed by said processor cause said processor to:

a. input and store a signal emitted by a sample in response to excitation energy applied thereto and acquired by a data acquisition system configured to measure said signal from the sample and average said signal over a plurality of measurements from the sample;

b. compute and store a set of singular values, said singular values corresponding to the real, non-negative eigenvalues of a correlation matrix constructed within a vector space created from said averaged signal, said vector space containing a noisefree signal subspace and a noise subspace, said singular values including noisefree singular values associated with said noisefree signal subspace, and noise singular values associated with said noise subspace;

c. determine whether a gap appears between a noisefree singular value and an adjacent noise singular value in a plot of said singular values, and if so, whether said gap stabilizes over one or more additional measurements of said signal from said sample;

d. request further measurements by said data acquisition system, if said gap cannot be identified or if said gap does not stabilize; and

e. command the data acquisition system to discontinue any further measurements, if the appearance and stability of said gap can be established.

18 – 24 (Canceled)

25. (previously presented) A computer-usable medium having stored therein computer-usable instructions for a processor, wherein said instructions when executed by said processor cause said processor to:

a. average over a number of data measurements from a sample to generate an averaged signal representing the data from the sample;

b. construct a correlation matrix from said averaged signal in a vector space defined using said averaged signal, said vector space including a noisefree signal subspace and a noise subspace;

c. diagonalize said correlation matrix to obtain the singular values and their corresponding eigenvectors, said singular values including noisefree singular values derived from said noisefree signal subspace, and noise singular values derived from said noise subspace; and

d. generate a graph of the singular values, and determine when a gap between a noisefree singular value and a noise singular appears in the graph and stabilizes, in order to establish that a sufficient number of data measurements have been performed for the sample so that measurements from the sample can discontinue.

26. (previously presented) A computer-usable medium having stored therein computer-usable instructions for a processor, wherein said instructions when executed by said processor cause said processor to:

a. measure one or more response signals emitted by a sample in response to excitation applied thereto;

b. average corresponding sample points in a plurality of signal measurements to generate a plurality of signal averaged sample points;

c. use said signal averaged sample points to form a vector space that comprises a noisefree signal subspace and a noise subspace;

d. construct a correlation matrix within said vector space and diagonalize said correlation matrix to obtain the singular values and their corresponding eigenvectors, said singular values including noisefree singular values associated

with said noisefree signal subspace, and noise singular values associated with said noise subspace;

e. generate a graph of the singular values, and determine when a gap appears between a smallest one of said noisefree singular values and a first one of said noise singular values, in a plot of said singular values, and whether said gap remains substantially stable after a plurality of iterations of steps a to d, to establish that a sufficient number of measurements has been reached for generating a substantially stable spectrum.

27. (previously presented) A computer-usable medium having stored therein computer-usable instructions for a processor, wherein said instructions when executed by said processor cause said processor to:

a. receive a set of singular values from a data acquisition system, said singular values representing the eigenvalue solutions of a correlation matrix constructed from a vector space creating using one or more response signals from a sample that have been averaged over a plurality of measurements for the sample, said vector space containing a noisefree signal subspace and a noise subspace, said singular values including noisefree singular values associated with said noisefree signal subspace and a noise subspace associated with said noise subspace;

b. generate a graph of the set of singular values, and determine whether a gap appears between a noisefree singular value and an adjacent noise singular value in a plot of said singular values, and if so, whether said gap stabilizes over one or more additional measurements of said signal;

c. request further measurements by said data acquisition system, if said gap cannot be identified or if said gap does not stabilize; and

d. command said data acquisition system to discontinue any further measurements, if the appearance and stability of said gap can be established.

28. (previously presented) A computer-usable medium having stored therein computer-usable instructions for a processor, wherein said instructions when executed by said processor cause said processor to:

a) apply one or more excitation pulses to a sample and measuring a response signal therefrom;

b) repeat step a) a plurality of times, and store for each of said repetitions an acquired transient;

c) sample each transient and average over all of said sampled transients to generate a collection of data points c_n (n = 1, . . . , N);

d) form an M-dimensional vector space using said sampled data points c_n (n = 1, . . . , N), said M-dimensional vector space comprising a noisefree signal subspace and a noise subspace;

e) construct an MxM correlation matrix within said M-dimensional vector space, and diagonalize said correlation matrix so as to extract therefrom a set of singular values

$$u_i \;(i = 1, \ldots, M);$$

f) generate a plot of said singular values u_i in M-space, said plot showing both noisefree singular values and noise singular values, wherein said noisefree singular values are associated with said noisefree signal subspace, and said noise singular values are associated with said noise subspace,

g) determine whether a gap appears between a smallest one of plotted noisefree singular values and the first one of said plotted noise singular values;

h) if said gap does not appear, repeating steps a to g one or more times until said gap can be identified;

i) determine whether said gap remains stable after a plurality of iterations of steps a to g; and

j) upon stabilization of said gap, convert said sampled data points into a frequency domain so as to generate a noise-reduced spectrum.